

$$f = \left(- \frac{\partial p}{\partial x} \right) \frac{D}{\frac{1}{2} \rho U_m^2} \Leftrightarrow f = \frac{8 \mu U_m}{R^2} \frac{D}{\frac{1}{2} \rho U_m^2}$$

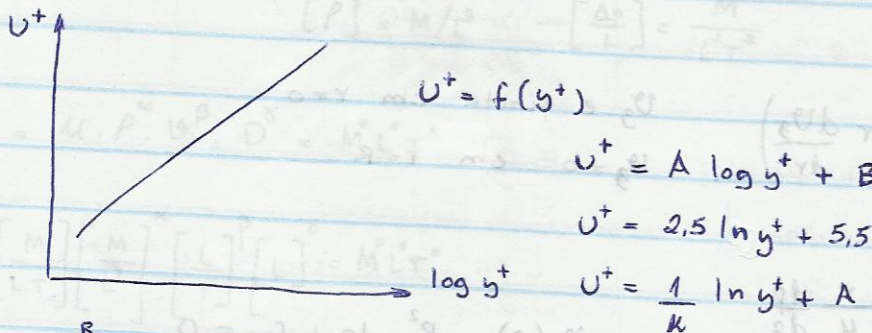
$$f = \frac{16 \mu D}{\rho U_m \frac{D^4}{4}} \Leftrightarrow f = \frac{64 \mu}{\rho U_m D} \Leftrightarrow \boxed{f = \frac{64}{Re}}$$

tensão na parede (superfície)

$$U^* = \sqrt{\frac{\tau_w}{\rho}} = U_\tau \rightarrow \text{velocidade de atrito}$$

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$$y^* = \frac{y}{U_\tau} = \frac{\mu / p}{U_\tau} \quad \frac{U}{U_\tau} = U^+ \quad \frac{y}{y^*} = y^+ = \frac{y}{\mu / U_\tau} = \frac{y \cdot U_\tau}{\mu}$$



$$U_m = \frac{\int_0^R U(r) 2\pi r dr}{\pi R^2}$$

$$U = U^+ \cdot U_\tau = U_\tau \left(\frac{1}{k} \ln y^+ + A \right) = U_\tau \left(\frac{1}{k} \ln(R-r) + A \right)$$

$$F(f, Re) = ?$$

$$y^* = \frac{y}{U_\tau} = \frac{\mu / p}{U_\tau} \quad U^* = \sqrt{\frac{\tau_w}{\rho}} = U_\tau$$

$$\frac{1}{\sqrt{f}} = -0.8 + 0.87 \ln(Re \sqrt{f}) \rightarrow \text{Prandtl - Karman - Nikuradse}$$

$$f = 0.316 Re^{-1/4} \quad \text{ou} \quad f = 0.184 Re^{-1/5}$$

Todreas Cheny onde $C = a + b_1 \left(\frac{P}{D} - 1 \right) + b_2 \left(\frac{P}{D} - 1 \right)^2$